Fleet-wide, GIS-based analysis of CCS retrofit opportunity

Chris Nichols

Office of Systems, Analyses and Planning, NETL

2010 NETL CO_2 Capture Technology Meeting

September 15th, 2010

Agenda

- **Introduction**
- **Phase I Review**
  - Methodology
  - GIS Examples
  - Metrics
  - Analyses
- **Phase II Overview**
  - Statement of Work Review
  - Comparison to Ph I

NATIONAL ENERGY TECHNOLOGY LABORATORY

Introduction

- **The Rationale**
  - Develop a database and Geographic Information Systems (GIS) analysis to model the cost and assist in the assessment of the feasibility of retrofitting/ refurbishing existing coal-fired power plants
  - Define sample populations of coal-fired power plants as candidates for potential:
    - Retrofit with CO_2 capture technology
  - Use the NETL study, *Carbon Dioxide Capture from Existing Coal-Fired Power Plants,* (Conesville Study) as a foundation in terms of cost and layout

Introduction (cont)

- **Phase I**
  - Conducted from July 2008 – September 2009
  - Published in January 2010
    - *Coal-Fired Power Plants in the United States: Examination of the Costs of Retrofitting with CO2 Capture Technology and the Potential for Improvements in Efficiency*
  - *Primary results of the analysis were cost curves of additional LCOE and cost of capture to retrofit the existing fleet*
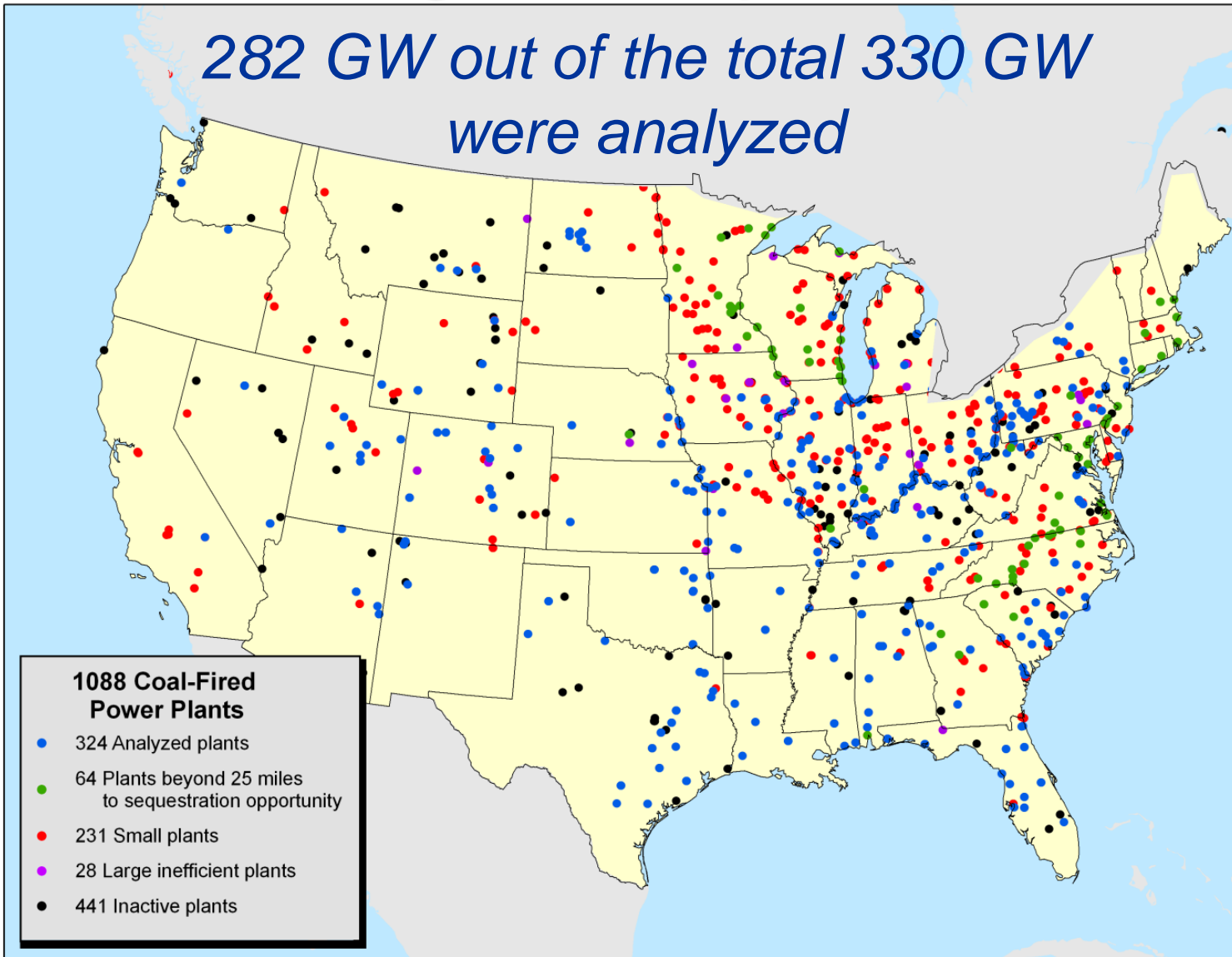- **Phase II**
  - Period of Performance from July 2010 – April 2011
  - Will refine sample population and methodology
- **Phases I and II performed by Enegis, LLC**

Defining the Sample Population

282 GW out of the total 330 GW were analyzed

1088 Coal-Fired Power Plants

- 🔵 324 Analyzed plants
- 🟢 64 Plants beyond 25 miles to sequestration opportunity
- 🔴 231 Small plants
- 🟣 28 Large inefficient plants
- ⚫ 441 Inactive plants

NATIONAL ENERGY TECHNOLOGY LABORATORY

Process

- **Calculate Levelized Cost of Electricity (LCOE) using Carbon Capture Model (CCM):**
  - Physical Size and Cost Scaling
  - Emissions Controls
  - Recirculating Cooling
  - Construction Difficulty
  - Multiple Units Discount
  - Additional Land Requirements
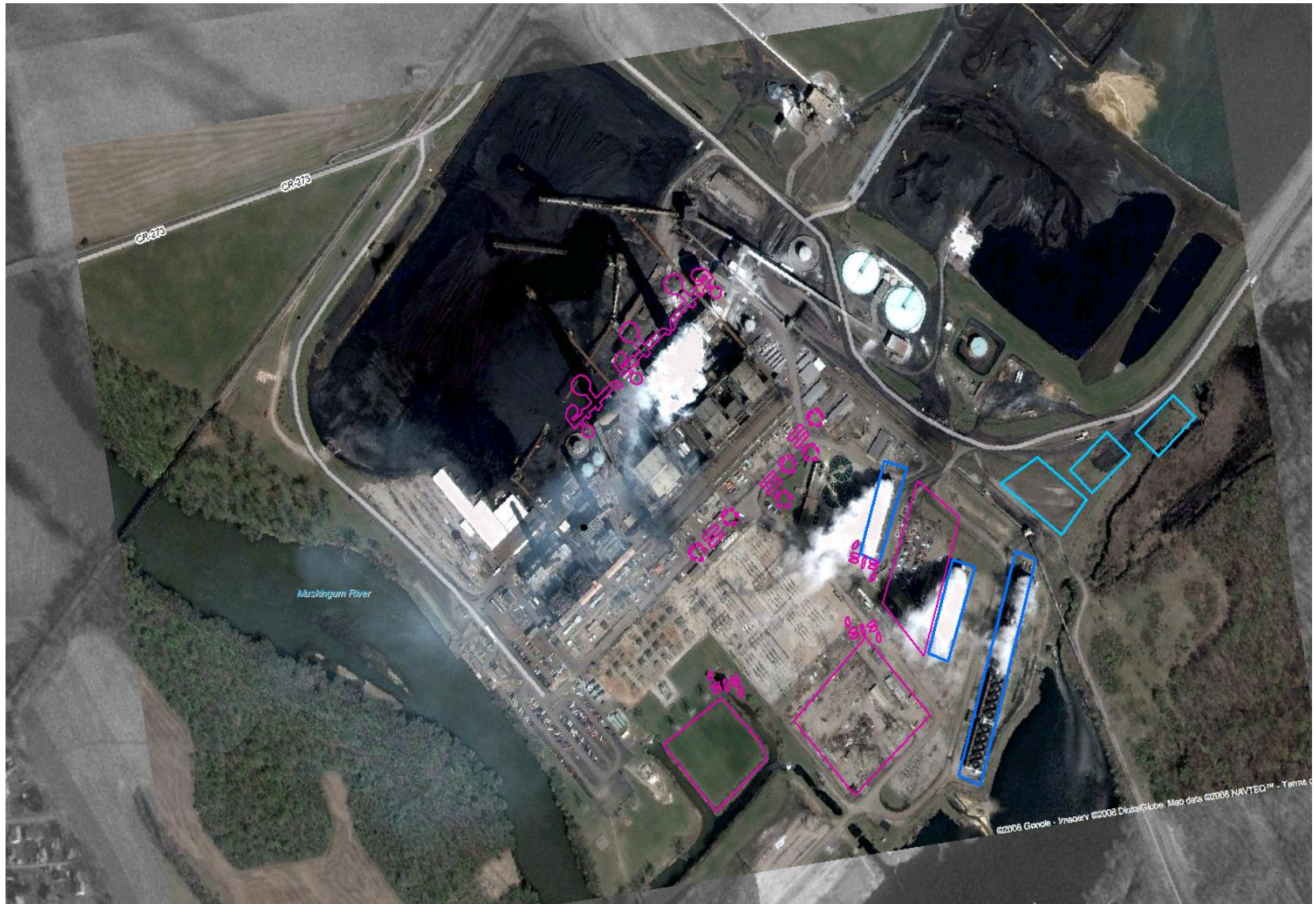 - CAPEX
  - OPEX
  - Parasitic Load

Physical Size and Cost Scaling

- **Physical Size and Cost Scaling**
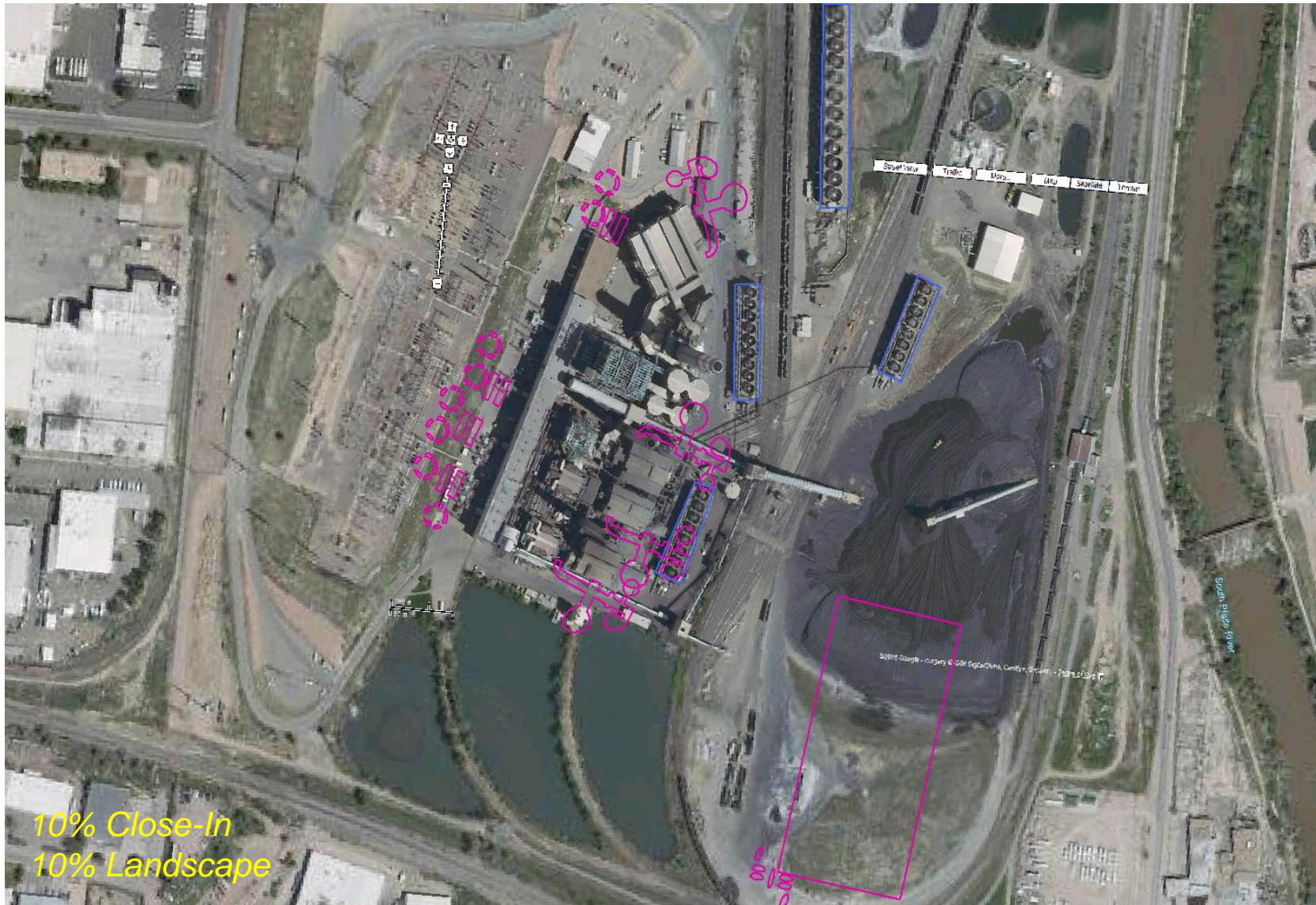

Plant 1497, AES Conesville, Coneville OH
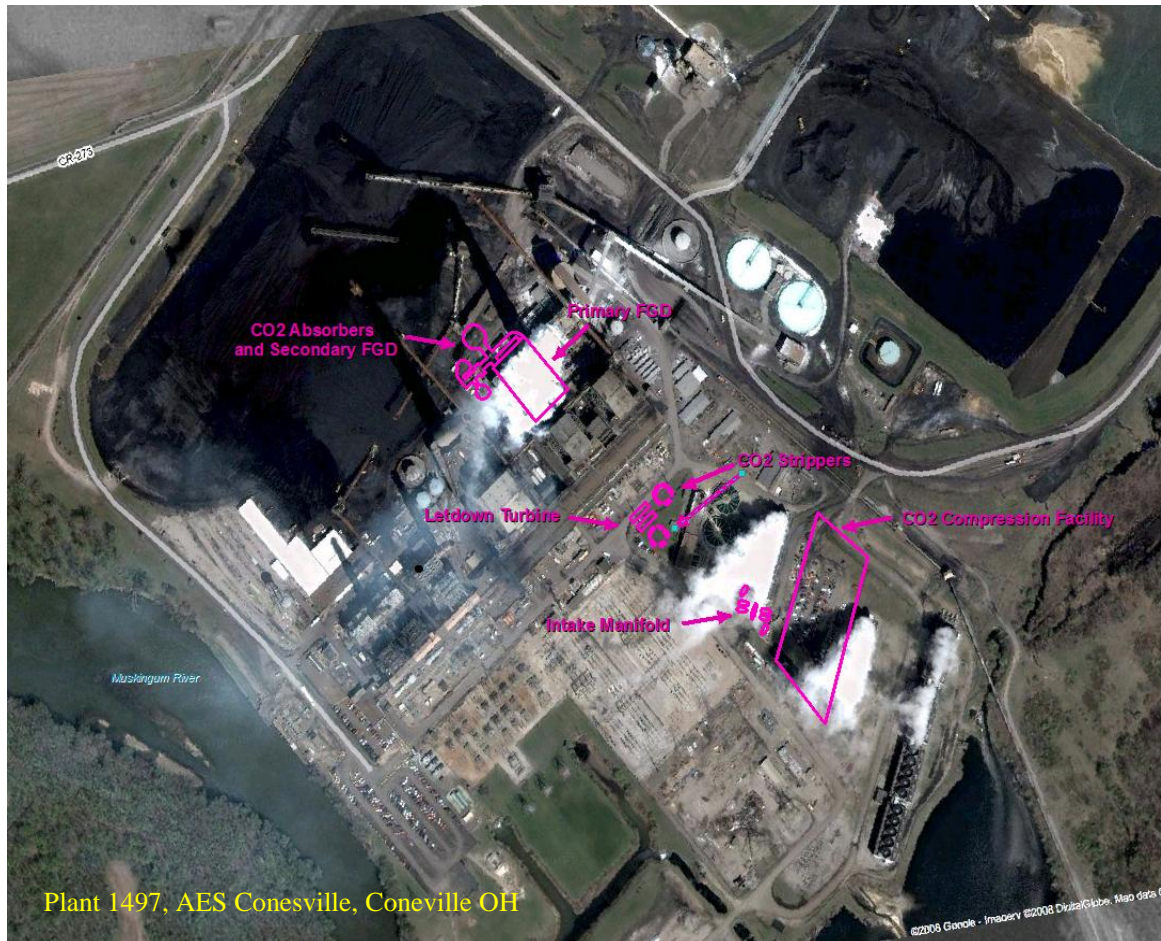
– **Required equipment geometries were digitized from the Conesville report so they could be scaled, relocated, and rotated to accommodate the remaining plants in the sample population**

NATIONAL ENERGY TECHNOLOGY LABORATORY

GIS Example – Conesville fully retrofitted

NATIONAL ENERGY TECHNOLOGY LABORATORY

GIS Examples (cont)

10% Close-In
10% Landscape

NATIONAL ENERGY TECHNOLOGY LABORATORY

GIS Examples (cont)

15% Close-In
0% Landscape

NATIONAL ENERGY TECHNOLOGY LABORATORY
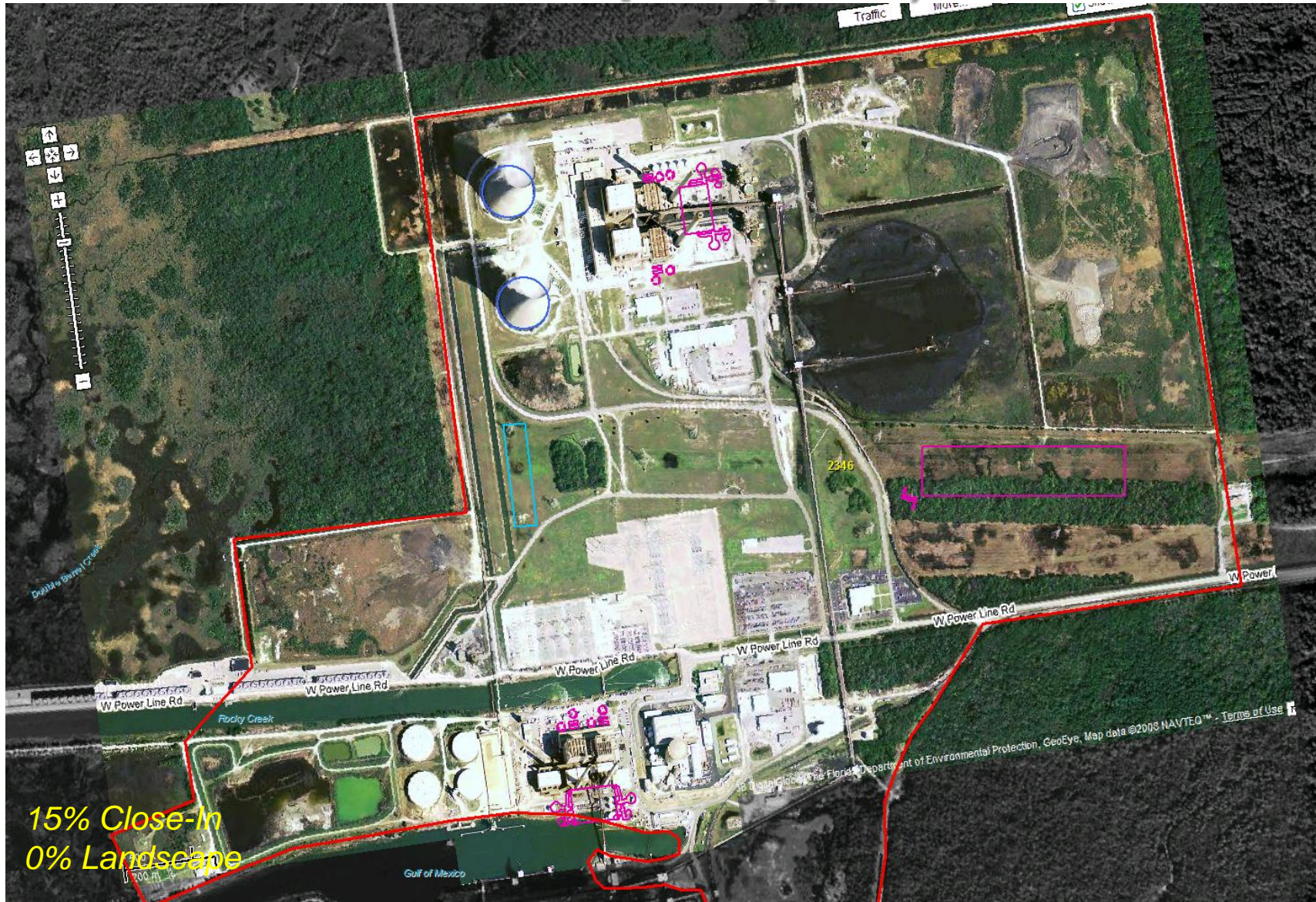
GIS Examples (cont)

Plant 1779 Warrick, Newburgh, IN

NATIONAL ENERGY TECHNOLOGY LABORATORY

Metrics—Levelized Cost of Electricity

- **20-Year Levelization Period**
  - Capital Charge Factor – 0.175
  - OM Levelization Factor – 1.1568
  - Fuelstock Levelization Factor – 1.1651

$$LCOE_P = \frac{(CCF_P)(TPC) + [(LF_{F1})(OC_{F1}) + (LF_{F2})(OC_{F2}) + \ldots] + (CF)[(LF_{V1})(OC_{V1}) + (LF_{V2})(OC_{V2}) + \ldots]}{(CF)(KWH)}$$

Where:

$LCOE$ = levelized cost of electricity over P years

P = levelization period (e.g., 10, 20, or 30 years)

CCF = capital charge factor for a levelization period of P years

TIC = total investment cost [the sum of bare erected costs (includes costs of process equipment, supporting facilities, direct and indirect labor), detailed design costs, construction/project management costs, project contingency, process contingency and technology fees]

LF_{Fn} = levelization factor for category n <u>fixed</u> operating cost

OC_{Fn} = category n <u>fixed</u> operating cost for the initial year of operation (but expressed in "first-year-of-construction" year dollars)

CF = plant capacity factor

LF_{Vn} = levelization factor for category n <u>variable</u> operating cost

OC_{Vn} = category n <u>variable</u> operating cost at 100% capacity factor for the initial year of operation (but expressed in "first-year-of-construction" year dollars)

KWH = annual net kilowatt-hours of power generated at 100% capacity factor

NATIONAL ENERGY TECHNOLOGY LABORATORY

Metrics—Captured and Avoided Carbon Cost

- **CO_2 Capture Cost**
  - Measures the cost per tonne CO_2 physically removed from a unit's flue gasses

- **CO_2 Avoided Cost**
  - Accounts for CO_2 produced in association with make-up power
  - Measures cost per tonne CO_2 actually avoided to the atmosphere

$$CO_2 \text{ Mitigation Cost} = (LCOE_{Cp} - LCOE_{Ref}) / (CO_{2Ref \text{ emitted}} - CO_{2Cp \text{ emitted}})$$

$$CO_2 \text{ Captured Cost} = (LCOE_{Cp} - LCOE_{Ref}) / (CO_{2Cp \text{ produced}} - CO_{2Cp \text{ emitted}})$$

Where:

CO_2 Mitigation Cost =	\$/ton of CO_2 avoided
CO_2 Captured Cost =	\$/ton of CO_2 removed
CO_2 =	Carbon dioxide (tons/kWh at plant capacity factor)
LCOE =	Levelized cost of electricity (\$/kWh)
Cp =	Capture plant
Ref =	Reference plant

Additional LCOE

Cumulative cost curve for all analyzed coal fired generating units built up from the site-level assessments for three capacity factors

282 GW (738 Units)

Chart: Cumulative % Nameplate vs. LCOE ($/MWH)

Legend:
- Conesville
- 65% CF
- 75% CF
- 85% CF

CO$_2$ Capture Cost

282 GW (738 Units)

Cumulative % Nameplate vs. CO$_2$ Capture Cost ($/tonne)
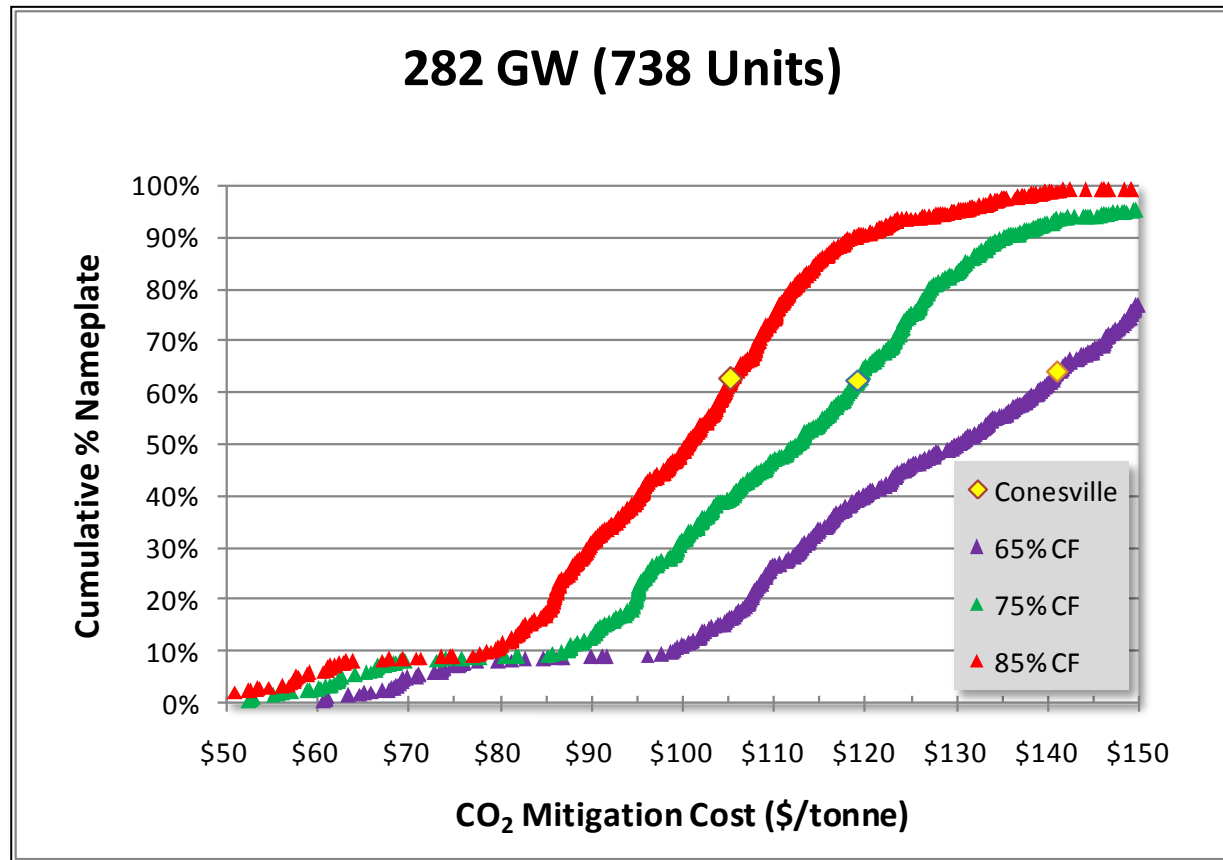
Legend:
- ◇ Conesville
- ▲ 65% CF
- ▲ 75% CF
- ▲ 85% CF
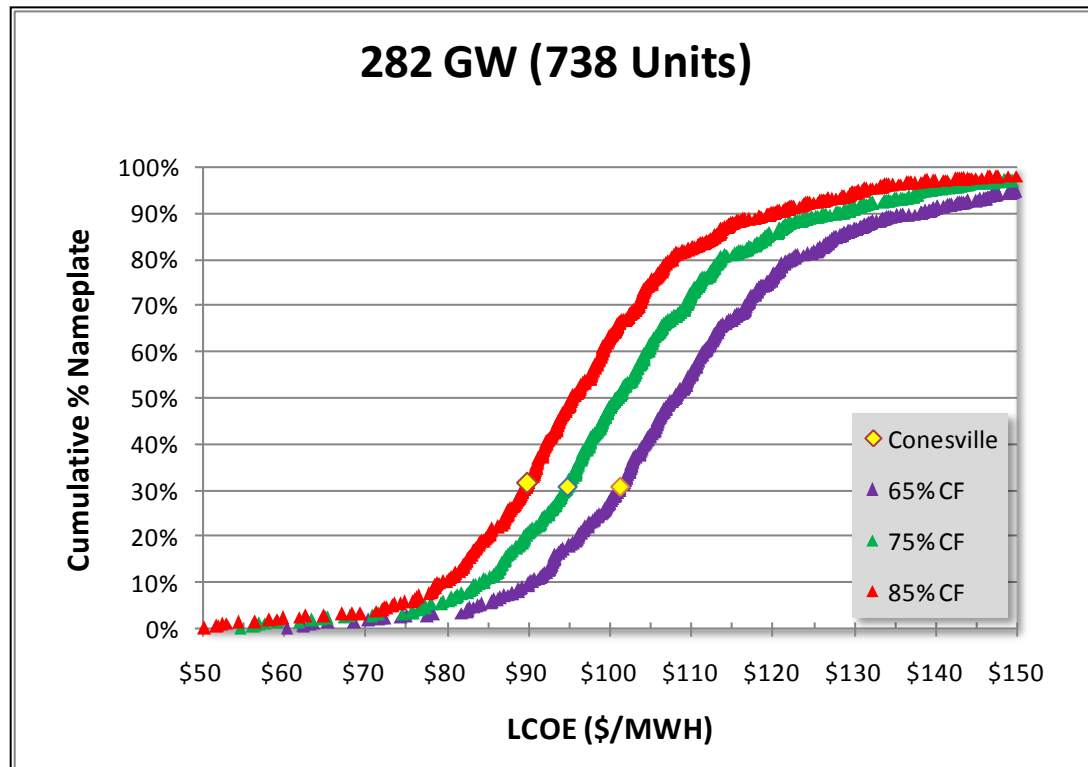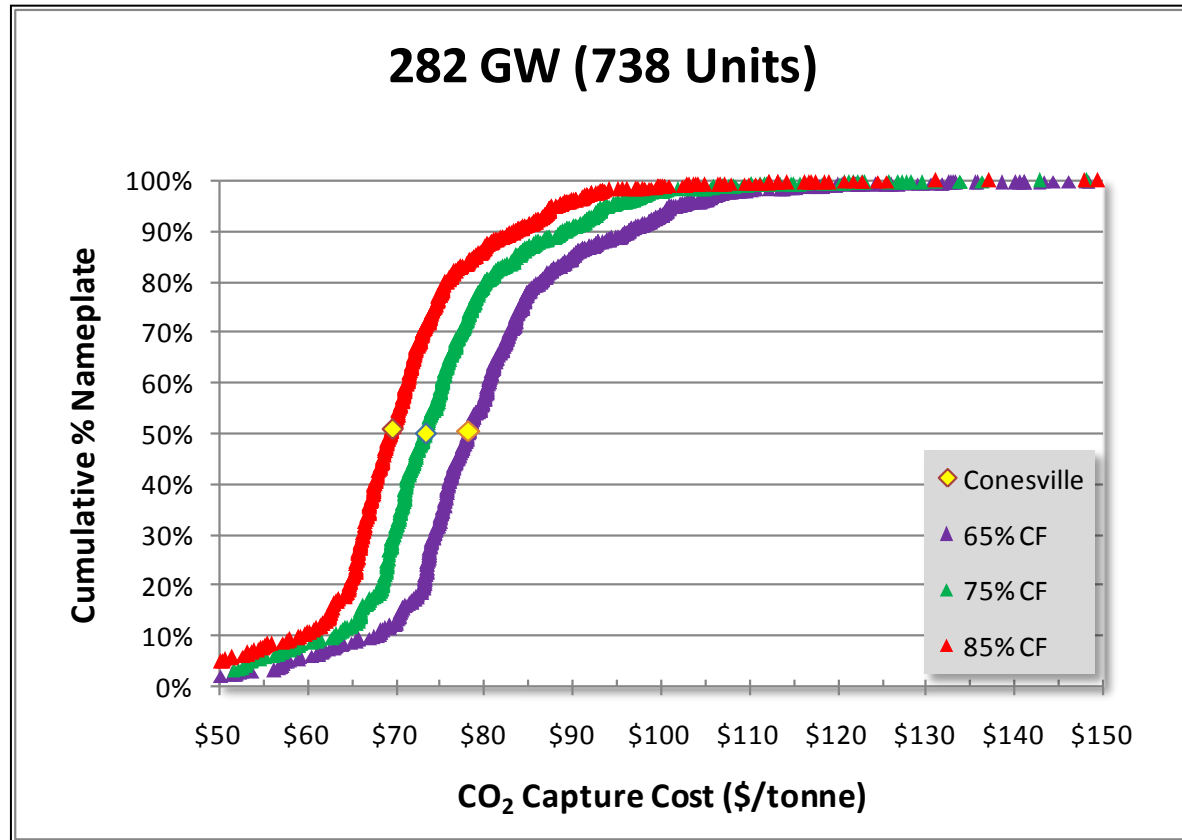
Inflection point around 80% of the fleet indicates a natural break point in likely retrofit opportunity

CO$_2$ avoided cost

282 GW (738 Units)

Cumulative % Nameplate

CO$_2$ Mitigation Cost ($/tonne)

Conesville
65% CF
75% CF
85% CF

Shape of these curves more irregular due to regional differences in make-up power and CO$_2$ intensity

Phase 2 of work

- **Objectives**
  - Further characterize sample sequestration opportunities (distance and capacity)
  - Refine the sample population criteria to operate on unit rather than total plant data
  - Expand cost and performance assumptions using recent public analyses
  - Incorporates industry input via steering committee
  - Incorporate sequestration costs
  - Consider additional capture technologies
  - Refine construction difficulty criteria

For more information…

- **NETL Energy Analysis website:**

http://www.netl.doe.gov/energy-analyses

Search for "retrofit":

-Report and appendix of all imagery

- **Contact me via phone or email:**

Chris Nichols

Christopher.nichols@netl.doe.gov

304 285-4172

NATIONAL ENERGY TECHNOLOGY LABORATORY

Coal-Fired Power Plants in the United States: Examination of the Costs of Retrofitting with CO_2 Capture Technology and the Potential for Improvements in Efficiency

(Original issue date December 2009)

Revision 1, January 29, 2010

DOE/NETL- 402/102309